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Regional Differences in Productivity Growth in The Netherlands:

An Industry-level Growth Accounting

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ABSTRACT

It is well known that the productivity growth in Europe is slowing down, against an increasing growth rate in the US. The Netherlands is one of countries in Europe with the lowest growth rates of productivity. This paper presents the results of a growth accounting exercise applied to regional industry data of The Netherlands between 1995-2002. We find that low productivity growth in The Netherlands is particularly situated in the economic core regions of the west and south and is caused by slow growth of MFP. Compared to the more peripheral regions, MFP-growth is lower in all industries, except social and non-market services. Part of this slow MFP-growth can be explained by the high level of traffic congestion and relatively low labour effort in the core regions

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1. Introduction

The main point in the current European policy debate is to find instruments that stimulate the growth rate of labour productivity. The reason for this is a persistent slowdown in labour productivity growth in European countries and an increasing gap in growth rates between the USA and Europe starting in the second half of the 1990's (see figure 1). Labour productivity in the US is nowadays at a much steeper growth path than in Europe. What is the reason for this increasing gap between Europe and the USA? This is an important question in order to assess the measures proposed in the Lisbon Agreement by the European Union (EU) to become the world's most competitive and dynamic knowledge-based economy in 2010. With increasing globalisation and deregulation of international markets, productivity growth is the tool to enhance competitiveness. Therefore instruments are sought that will get the productivity growth rate in European countries back on track.

One of the main explanatory factors for productivity growth is the production, use and diffusion of information technology (IT).[1] Timmer et al (2003), Inklaar et al. (2003) and Daveri (2004) show, however, that the main source for the European slowdown in productivity growth is not so much lagging IT use, but a deceleration of non-IT capital deepening (i.e. lagging increase of non-IT capital per hour worked) and, in contrast to the US, a lack of acceleration of MFP growth. MFP growth is the residual part of productivity growth that cannot be attributed to changes in labour quality and capital assets, usually subdivided in IT capital and non-IT capital.

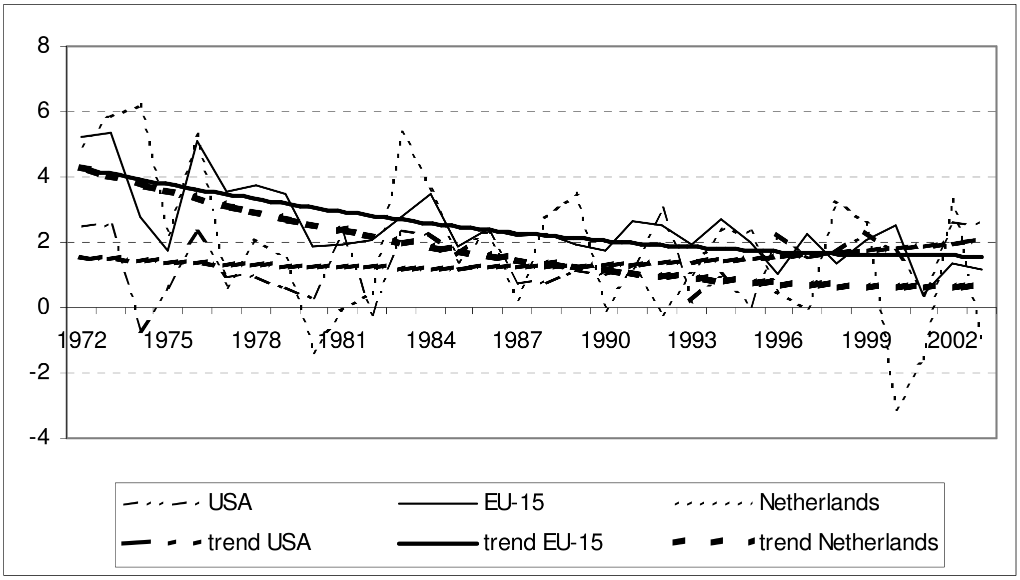
The deceleration of non-IT capital deepening of the nineties in Europe has coincided with a sharp rise in employment. Non-IT capital deepening, or the growth of non-IT capital per hour worked, is clearly related to the growth rates of the price of both inputs. Faster wage growth increases non-IT capital deepening because capital will substitute labour. An increase in the 'price' of non-IT-capital, on the other hand, makes capital more expensive and leads to deceleration of non-IT capital deepening. Inklaar et al. (2003), however, show that the impact of growth rates of wages and rental prices on non-IT capital deepening is much stronger for the US than Europe. The small effect of wage growth in European countries implies that wage moderation might be an important reason for the slowdown of non-IT capital deepening.

Figure 1 shows that productivity growth in The Netherlands is at a persistently lower growth path than the European average. Since Dutch government policy has been directed at a sustained moderation of wages since the early 1980's, a natural question to ask is whether this has led to an even slower rate of non-IT capital deepening than Europe or that other mechanisms have instead caused the Dutch slowdown of productivity growth. This issue will be addressed at a low spatial level: what is the reason for the Dutch slowdown, are there regions that have contributed more to the lagging productivity growth rate than others and which industries are responsible.

This question will be answered using the growth accounting approach, which is also used to explain the widening of the productivity growth gap between Europe and the USA.[2] At the provincial level of The Netherlands distinction can be made between growth rates of value added in constant prices, number of hours worked, the level of education of labour and IT and non-IT capital services for eight aggregate industries. This provides enough detail to determine the industry contribution by province to the lagging Dutch growth performance of the late 1990's. This issue is useful from both an academic and a policy perspective.

[1] In this paper the expression information technology (IT) is also used when reference is made to information and communication technology (ICT) in for example related studies. In the empirical part of this paper only IT equipment (computers, related equipment and software) can be distinguished.
[2] See e.g. Jorgenson and Stiroh (2000), Oliner and Sichel (2000,2002), Inklaar et al. (2003) and McGuckin and van Ark (2004).

Figure 1. Trends in real labour productivity growth rates (%) in the USA, Europe and The Netherlands, 1972-2003



Source: DDGC, Total Economy Database (www.ggdc.net)

This paper is organised as follows. Section 2 considers the track record of productivity growth in The Netherlands from previous studies on the explanation of the productivity gap between the US and EU. In section 3 the method of industry growth accounting is described. Section 4 presents the outcome when this technique is applied to province data for The Netherlands. The Dutch perspective will then be discussed at the regional level bearing in mind the results from section 2. Finally section 5 concludes.

2. The Dutch productivity growth performance in perspective

Starting from a higher level in 1980, and continuing through to the early 1990s, it was in the second half of the 1990's that the growth track of GDP per hour worked in Europe fell below that of the US. For The Netherlands, however, the decline relative to Europe had already set in in the second half of the 1970's (figure 1). Between 1972 and 1976 productivity in The Netherlands grew faster than in Europe since the Dutch level moved from 141% of the average EU-level in 1972 to 147% in 1976. This shows that The Netherlands do have a very high level of labour productivity, but that, as figure 1 clearly shows, this advantage quickly erodes as the productivity growth rate falls short of the European average for a sustained period of time.

From 1976 onwards the productivity gap in The Netherlands relative to the EU has closed by 34 percentage points, from 147% of the EU level in 1976 to 113% in 2003.[3] So unless productivity in The Netherlands reverts to a higher growth path, Europe will overtake the Dutch level around 2015, given the average rate of decline of Dutch productivity growth relative to Europe of the past 30 years. The USA, who still have a lower productivity level than The Netherlands, will surpass the Dutch level in 2010, given the strong US productivity growth rate between 1995-2002. It will therefore be no surprise the Dutch authorities make a

[3] Based on the GGDC Total Economy Data Base, at www.ggdc.net.

strong effort of finding policy measures that will put the Dutch productivity growth rate back on track.

What explanation can be given for the diverging growth paths between the EU and The Netherlands, or between the USA and The Netherlands for that matter? Explaining the gap between The Netherlands and the US falls in the same category of studies that have attempted to explain the gap between Europe and the US.

Empirical evidence, mainly for the United States highlights the importance of IT for generating growth. Evidence first emerged of a significant impact of investment in IT capital on output and productivity growth (Jorgenson and Stiroh, 2000, Oliner and Sichel, 2000). Several firm-level studies found that spillovers from IT capital exist (Brynjolfsson and Kemerer, 1996). Brynjolfsson and Hitt (2000) find evidence of a substantial relationship between computers and MFP-growth, and that these contributions rise significantly in the long-term because computers complement productivity-enhancing organisational changes carried out over a period of years. This IT capital deepening channel also operates in the EU but with lower contributions than in the US. Real IT investment and capital service flows in the European Union have grown almost as rapidly as in the US, but the level of IT investment either as a share of total equipment or as a percentage of total GDP has remained well below that of the US and it has not shown any sign of catch-up during recent years (van Ark et al., 2002b; Timmer et al., 2003).

Timmer at al (2003), using aggregate data, highlight the important role played by falling growth rates of non-IT capital per hour worked (non-IT capital deepening) and MFP growth in Europe, while these increased in the USA, comparing the second half of the 1990's to 1980-1994. Inklaar et al. (2003), using industry data, corroborates these results. They find that manufacturing industries are responsible for around one-third of the aggregate European deceleration in non-IT capital deepening, which is much bigger than their GDP share. Another major part of this European deceleration is due to business services.[4]

Table A1 of Appendix 1 presents a summary of the findings of Inklaar et al. (2003) for The Netherlands in the period 1995-2000, which will guide the explanation of our regional growth accounting later on. Table A1 shows that the slow growth rate of The Netherlands is primarily a result of low MFP growth, particularly in manufacturing of electronics and instruments and in financial intermediation. Wholesale trade, on the other hand, made a relatively strong positive contribution to productivity growth in The Netherlands.

What can be said about labour productivity at regional levels within The Netherlands? Capital-intensive industries are still responsible for high levels of labour productivity in The Netherlands.[5] Regions with a high concentration of basic metal or chemical industries have significantly higher productivity levels than average. These are usually coastal regions with a major seaport (Terneuzen, Rotterdam-Rijnmond, IJmuiden/Velzen and Delfzijl). On the other hand, high productivity levels are also found in regions with a high share of knowledge intensive services (Amsterdam, Utrecht, The Hague, Groningen). In general terms, Figure 2 shows that high productivity levels are found in the west and south of the country, while low levels are found at the eastern border. The regional real growth rates of labour productivity in Figure 3 show that the central part of The Netherlands has relatively high growth rates as well as the northeast.

[4] Differences between these studies can be related to countries included and deflators The results of Timmer et al for the EU-15 and The Netherlands are based on $ US of 1999 in PPP. Inklaar et al use data in euros of 1995 for the EU-4 (Germany, France, U.K and Netherlands). For IT producing industries in the European countries US deflators for semiconductors are used.

[5] All regional data in this paper are excluding mining (ISIC 10-14) and real estate (ISIC 70).

Figure 2. Labour productivity 2002 (euro per hour)

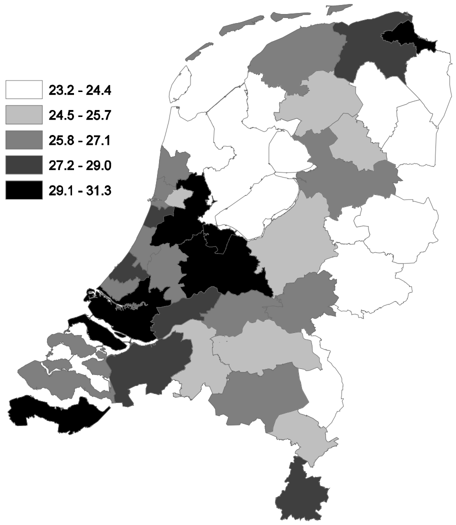
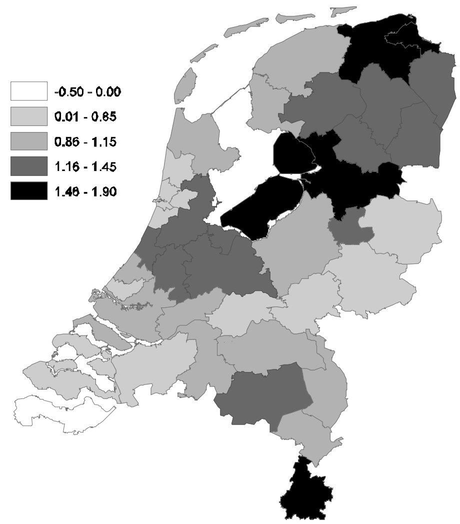


Figure 3. Real annual labour productivity growth 1990-2002 (%)

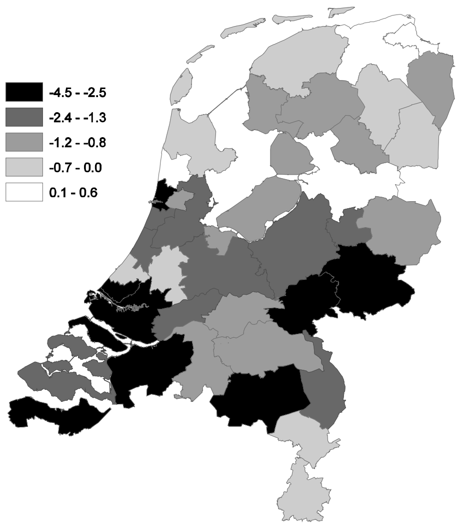


The main issue of the remainder of this paper is to interpret Dutch productivity growth in a spatial perspective: can certain industries in certain regions be identified that account for the slowdown in Dutch productivity growth relative to Europe? In addition: what is the reason for the slowdown in that particular case? Reasons to be distinguished by industry are: quality of labour, IT capital deepening, non-IT capital deepening, MFP-growth and employment reallocation. This latter aspect denotes the extent to which employment growth has been concentrated in low productivity sectors.

This issue is addressed using growth accounting techniques on data between 1995-2002 on eight industries for 12 provinces in The Netherlands. The availability of only a limited number of industries means that no distinction can be made between IT producing, IT using and non-IT industries for each separate region. We can however pinpoint the composite industry in each region that can be held accountable for slowing down productivity growth in that region and in that sense in the country as a whole.

Figure 4 shows which regions have had decelerating productivity growth between 1990-1994 and 1995-2002 (the darker the colour, the larger the deceleration) and those that have had accelerating growth rates between the two periods (the white areas). In most regions productivity growth indeed fell in the period 1995-2002 compared to 1990-1994. The largest deceleration took place in the southern part of the country. Only four regions, all located in the northern part, have had accelerating productivity growth rates between the two periods. Figure 4 thus makes it likely that the slowdown of Dutch productivity growth in the 1990's relative to Europe and the USA (figure 1) is caused primarily by industries located in the southern half of the country. This part however consists of the regions constituting the economic heart of The Netherlands. This assertion will be formally investigated in the sequel.

Figure 4. Acceleration/deceleration (+/-) in real annual labour productivity growth between 1995-2002 en 1990-1994



3. Growth accounting

3.1. Introduction

The economic theory of productivity measurement goes back to Solow (1957). It has since developed due to major contributions of Jorgenson (1995), Griliches (1995) and Diewert (Diewert and Nakamura (2005). They reformulated productivity measures in a production function setting and linked it to the analysis of economic growth. This production theoretical approach to productivity measurement is consistent with and integrates the neoclassical theory of the firm, index number theory and national accounts. It is called growth accounting.

This growth accounting technique examines how much of the observed rate of change of an industry's output can be explained by the rate of change of the combined inputs. To construct an index of combined inputs, the rates of change of different inputs (labour, capital) have to be weighted appropriately. With these weights, index number theory comes in. From production theory, in addition to some simplifying assumptions, it can be shown that these weights are equal to the factor income shares, e.g. the share of labour compensation in total costs. These income shares approximate production elasticities, i.e. the effects of a 1% change in the individual inputs to output.

As an alternative to growth accounting it is also possible to use the econometric approach to productivity measurement. This approach is based on observations of output and input volume, without postulating relationships between production elasticities and income shares beforehand. Instead these possible relations can be tested empirically. However, this comes at a price since it is difficult to make a link with economic theory, due to complex econometric issues, lack of robustness and the sample size of observations (OECD, 2001). However, the growth accounting and econometric approach are not competitors, but can instead supplement one another (Hulten, 2001). Econometric methods can be applied to further explain the productivity residual from growth accounting. This study applies the basic tools of the growth accounting approach to industry-level output and inputs in different regions. The residual MFP-growth rate that we find will subsequently be explained using econometric methods.

3.2. Derivation of growth accounting model

This section briefly outlines the derivation of the growth accounting equations from the microeconomic neoclassical theory of production and a number of related assumptions (OECD, 2001). The assumptions are listed below.

- The production technology can be represented by a production function relating output (Q) to primary inputs labour (L) and capital (K), as well as to (secondary) intermediate inputs, like material, services and energy. Our study abstains from intermediate inputs because they are not available at the regional level. This means that our production function relates value added (Y) to only the primary inputs L and K.

$$Y = \Phi(L, K)$$

- The production function exhibits constant returns to scale.
- Labour and capital can be heterogeneous. Different types (qualities) of labour and capital can be identified, e.g. N type of labour, L_1, L_2,…, K_N and M types of capital, K, K_2,…, K_M.
- Productivity changes are so-called Hicks-neutral, i.e. they correspond to an outward shift (A) of the production function

$$Y = A \cdot F(L, L_2, .., L_N, K_1, K_2, .., K_M)$$

- The firms' objective is cost minimisation subject to the production function above
- Labour inputs can be hired at any moment against the market rate w_i (i=1,.., N)
- Capital inputs require investments in different types of capital or hiring of capital. Every investment adds to the capital stock from which capital services (i.e. the capital input in production) are derived. This derivation involves the rates of return and of depreciation of capital, which yield the rental price of capital of type j, r_j (see Appendix 3)

This gives rise to the following optimisation problem

$$\text{Minimise } C = \sum_{i=1}^{N} w_i L_i + \sum_{j=1}^{M} r_j K_j$$
$$\text{subject to } Y = A \cdot F(L, L_2, .., L_N, K_1, K_2, .., K_M)$$

which yields the usual optimality conditions for each input. For labour this means hiring until marginal revenues ($A \partial F / \partial L_i$) equal marginal costs (w_i/p), where p is the output price. For capital input the analogy is true.

Since we are focusing on growth, the production function should be differentiated with respect to time

$$\frac{d \log Y}{dt} = \sum_{i=1}^{N} \frac{(\partial F / \partial L_i) L_i}{F} \cdot \frac{d \log L_i}{dt} + \sum_{j=1}^{M} \frac{(\partial F / \partial K_j) K_j}{F} \cdot \frac{d \log K_j}{dt} + \frac{d \log A}{dt}$$

Since $\partial F / \partial L_i = w_i / Ap$ and AF=Y, we have

$$\frac{d \log Y}{dt} = \sum_{i=1}^{N} \frac{w_i L_i}{pY} \frac{d \log L_i}{dt} + \sum_{j=1}^{M} \frac{r_j K_j}{pY} \frac{d \log K_j}{dt} + \frac{d \log A}{dt} \qquad (1)$$

3.3. Decomposition of labour productivity growth

Rewriting equation (1) in a simple discrete time framework gives our point of departure for decomposing the growth rate of output of each region-industry combination in

$$\Delta \log Y_t = v_t^L \Delta \log L_t + v_t^K \Delta \log K_t + \Delta \log MFP_t \tag{2}$$

where Δ is the difference operator, so $\Delta\log Y$ is the growth rate of real gross value added in constant prices, $\Delta\log L$ is the growth rate of labour input and $\Delta\log K$ is the growth rate of capital input in constant prices. Here v^L is the share of current price labour compensation in current price value added, v^K is the same for capital compensation in value added and finally *MFP* is the total factor productivity, or *A* in equation (1).

In this study we can distinguish three different types of labour quality based on educational attainment: high, intermediate and low (h =3). Capital can be distinguished in IT and non-IT capital (j =2). Growth of labour and capital input is defined as the growth rate of each type of labour and capital, respectively, weighted by their two-period average share in total nominal input compensation

$$\Delta \log L_t = \sum\nolimits_h v_{h,t}^L \Delta \log L_{h,t} \tag{3}$$

$$\Delta \log K_t = \sum\nolimits_j v_{j,t}^K \Delta \log K_{j,t} \tag{4}$$

where

$$v_{h,t}^L = \frac{1}{2}\left(\frac{w_{h,t} L_{h,t}}{\sum_h w_{h,t} L_{h,t}} + \frac{w_{h,t-1} L_{h,t-1}}{\sum_h w_{h,t-1} L_{h,t-1}} \right) \tag{5}$$

and

$$v_{j,t}^K = \frac{1}{2}\left(\frac{r_{j,t} K_{j,t}}{\sum_j r_{j,t} K_{j,t}} + \frac{r_{j,t-1} K_{j,t-1}}{\sum_j r_{j,t-1} K_{j,t-1}} \right) \tag{6}$$

and $w_{h,}$ is the wage rate for labour of education level h and r_j is the rental price of capital of asset type j. Finally, L_h is the number of hours worked by labour of education level h and K_j is the capital stock of asset type j. The weights in (5) and (6) are related to the fact that we have heterogeneous labour and capital that cannot be aggregated by simple adding up. Therefore weights or index number are required. The results of this weighted aggregation depend on the index number used. The best option in this respect is to use the so-called Törnquist index, which is represented in (5) and (6) and throughout the sequel of this section (see for more details OECD, 2001; Chapter 7).

The shares of labour and capital compensation in value added of equation (2) are calculated as

$$v_t^L = \frac{1}{2}\left(\frac{\sum_h w_{h,t} L_{h,t}}{p_t Y_t} + \frac{\sum_h w_{h,t-1} L_{h,t-1}}{p_{t-1} Y_{t-1}} \right) \tag{7}$$

and

$$v_t^K = \frac{1}{2}\left(\frac{\sum_j r_{j,t} K_{j,t}}{p_t Y_t} + \frac{\sum_j r_{j,t-1} K_{j,t-1}}{p_{t-1} Y_{t-1}}\right) \tag{8}$$

Next, the growth of labour quality is defined as the difference between labour input in (3) and growth of total hours worked.

$$\Delta \log q_t^L = \sum_h v_{h,t}^L \Delta \log L_{h,t} - \sum_h \Delta \log L_{h,t} = \Delta \log L_t - \Delta \log H_t \tag{9}$$

H_t is defined as the sum of hours over the different labour types. Equation (2) can be rearranged in terms of labour productivity, represented by $y=Y/H$

$$\Delta \log y_t = \Delta \log Y_t - \Delta \log H_t = v_t^L \Delta \log q_t^L + v_t^K \Delta \log k_t + \Delta \log mfp_t \tag{10}$$

where $k=K/H$ is the ratio of capital services to hours worked and the residual term is again labelled *MFP*, but this time in small letters. The distinction between capital goods by asset type (IT assets and non-IT assets) makes that (10) can be rewritten as

$$\Delta \log y_t = v_t^L \Delta \log q_t^L + v_t^K \left(\sum_{j \in IT} v_{j,t}^K \Delta \log k_{j,t} + \sum_{j \in N} v_{j,t}^K \Delta \log k_{j,t}\right) + \Delta \log mfp_t \tag{11}$$

We now define IT capital deepening as the growth rate of the ratio of IT capital to hours worked, or $\Delta \log k_t^{IT} = \sum_{j \in IT} v_{j,t}^{IT} \Delta \log k_{j,t}$, and the growth rate of IT capital is weighted like before with the average share of capital compensation of each IT asset in total IT capital compensation of the past two years

$$v_{j,t}^{IT} = \frac{1}{2}\left(\frac{r_{j,t} K_{j,t}}{\sum_{j \in IT} r_{j,t} K_{j,t}} + \frac{r_{j,t-1} K_{j,t-1}}{\sum_{j \in IT} r_{j,t-1} K_{j,t-1}}\right)$$

Non-IT capital deepening is defined analogously. Equation (11) can next be simplified into

$$\Delta \log y_t = v_t^L \Delta \log q_t + v_t^{IT} \Delta \log k_t^{IT} + v_t^N \Delta \log k_t^N + \Delta \log mfp_t \tag{12}$$

where N refers to non-IT capital and

$$v_t^{IT} = \frac{1}{2}\left(\frac{\sum_{j \in IT} r_{j,t} K_{j,t}}{p_t Y_t} + \frac{\sum_{j \in IT} r_{j,t-1} K_{j,t-1}}{p_{t-1} Y_{t-1}}\right) \tag{13}$$

Equation (12) shows that real labour productivity growth can be decomposed into four different sources: (i) labour quality, (ii) IT capital deepening, (iii) non-IT capital deepening and (iv) MFP growth. This decomposition can be made for each distinctive industry level for which data are available. The aggregation of industries to an overall national or regional level is treated in the next section.

3.4. Aggregation

In order to get economy-wide indicators of outputs (productivity growth) and inputs (quality growth and capital deepening) simply summing industry values requires strict requirements (Jorgenson, 2002, Inklaar, et al, 2003). We make as little assumptions beforehand as possible and take output and input prices to reflect marginal productivities. Input prices can differ between industries for example because of differences in factor mobility. For this aggregation method it is necessary to weight industry growth rates of output and inputs by their share in aggregate value added.

Like the shares used in the decomposition of labour productivity growth of the previous subsection, we also use a Törnquist index of value added of industry *i* in total value added

$$v_{i,t}^{Y} = \frac{1}{2}\left(\frac{Y_{i,t}}{\sum_i Y_{i,t}} + \frac{Y_{i,t-1}}{\sum_i Y_{i,t-1}} \right) \tag{14}$$

For adequate country comparisons of output and inputs use should be made of industry-specific purchasing power parities because industry output prices likely differ between countries. However, when regions within a country are concerned we assume no regional difference in purchasing power, so the actual regional price deflators are used, when available. Aggregation of regions to the country-level, or some other spatial level for that matter, is carried in the same way as industry aggregation, i.e. by weighting with the appropriate regional industry shares in value added.

3.5. Industry contribution to productivity growth

Aggregate value added growth, based on each industry *i*, is defined as

$$\Delta \log Y_t = \sum_i v_{i,t}^{Y} \Delta \log Y_{i,t} \tag{15}$$

where the weight *v* is defined in (14). Aggregate hours worked are simply summed over all industries: $H_t = \Sigma_i H_{i,t}$.

Labour productivity growth is calculated by subtracting the growth rate of real value added by the growth in total hours worked, or $\Delta \log y_t = \Delta \log Y_t - \Delta \log H_t$. Using the aggregation procedure of (15) enables us to decompose aggregate labour productivity growth as

$$\begin{aligned} \Delta \log y_t &= \sum_i v_{i,t}^{Y} \Delta \log Y_{i,t} - \sum_i \Delta \log H_{i,t} = \\ &\sum_i v_i^{Y} \Delta \log y_{i,t} + \left(\sum_i v_{i,t}^{Y} \Delta \log H_{i,t} - \Delta \log H_t \right) \end{aligned} \tag{16}$$

where the terms between brackets equals reallocation of hours worked to high productivity industries (Nordhaus, 2002, Stiroh, 2002). In the first term between brackets the industry value added share weights hours' growth. The second term merely states that aggregate hours growth weights industries by their lagged share of aggregate hours. The reallocation term shows that the movement of labour from low-productivity-level industries to high-productivity-level industries will raise productivity even when the actual productivity growth rates in both industries is zero. In other words, this term is positive when industries in an above average labour productivity level show positive employment growth or likewise with below-average productivity levels have falling employment. Negative values show that high productivity industries and industry employment growth do not go hand in hand.

When combining IT or non-IT capital deepening by industry with their shares in value added, we get the contribution of IT or non-IT capital deepening in each industry to aggregate labour productivity growth. Omitting the time subscript *t* equations (12), (15) and (16) reflect the contribution of the inputs and MFP-growth for each industry to aggregate productivity growth

$$\Delta \log y = \sum_i v_i^Y \left(v_i^L \Delta \log q_i^L + v_i^{IT} \Delta \log k_i^{IT} + v_i^N \Delta \log k_i^N + \Delta \log mfp_i \right) + R \qquad (17)$$

where *R* is the reallocation of working hours defined in (16). Equation (17) also shows that aggregation over industries requires weighting with the industry share in value added.

The contribution of IT capital deepening of industry *i* to aggregate productivity growth equals

$$LPCON_i^{IT} = v_i^Y \left(v_i^{IT} \Delta \log k_i^{IT} \right) \qquad (18)$$

The contribution of the other industry inputs to aggregate productivity growth is defined analogously.

3.6. Data issues

This subsection briefly summarises the main data issues that arise when conducting this regional industry growth accounting for The Netherlands. More details are available in Appendix 3.

Output

In each region, output by industry is measured as value added. In all regions, mining (ISIC 10-14) and real estate (ISIC 70) are omitted from the analysis throughout this paper. As output deflator the regional GDP price index by industry is used, which is defined as the national GDP deflator adjusted to the regional sector composition. This regional price index is only available at a very high level of industry aggregation, which limits the industrial detail for each region.

Labour

Regional labour input by industry is measured as the total number of hour worked by both employees and self-employed. Regional hours worked by employees are simply the number of full-time equivalent (fte) jobs by industry per region times the annual working hours for full-time jobs by industry nation-wide. Regional self-employment by industry is taken into account by adjusting regional working hours of employees by the ratio of self-employed to employees by industry nation-wide.

Capital

Regional capital inputs by type of capital good (IT vs. non-IT) by industry are measured as capital service flows. This means that each type of capital good is based on its user cost. Capital services are defined as the flow of productive services from the cumulative capital stock, based on the combination of past investments and depreciation rates. The flow of services from any asset is generally assumed to be proportional to the capital stock.

At a detailed industry level, particularly for IT-manufacturing industries, no adequate deflators are available for specific IT assets, like semiconductors, that take account of the rapid increase in their performance and quality. For that reason country comparisons are often made using harmonised US price deflators on semiconductors for all countries involved. However, our regional data do not allow for in-depth industry details by distinguishing specific IT producing or IT using industries. Therefore it is more appropriate to use national IT investment price deflators instead of US deflators for detailed investment goods. Similarly, for other non-IT investment goods the national deflator on total investment is used.

Labour quality
Regional labour quality is based on the regional employed labour force by industry and educational level, where distinction is made in low, intermediate and high levels of education. For each region and industry the employment shares by educational level are used to obtain regional and industry hours worked by education.

Labour compensation
National information of hourly employee wages by industry and education multiplied by regional hours worked by industry and education yields regional labour compensation per hour worked.

Sample period
For most variables information for a substantial period of time is usually available, i.e. 1987-1995. This implies that differences in the first and second half of the 1990's can be distinguished. For data on investment in IT and non-IT capital by industry, however, the sample period is limited to 1995-2002. In other words, the sample period with which to conduct a regional growth accounting exercise for The Netherlands is 1995-2002, where the contribution to regional labour productivity can be determined of labour quality, IT capital deepening, non-IT capital deepening and MFP-growth. For more details on the definition and sources of the data we refer to Appendix 3.

4. Results

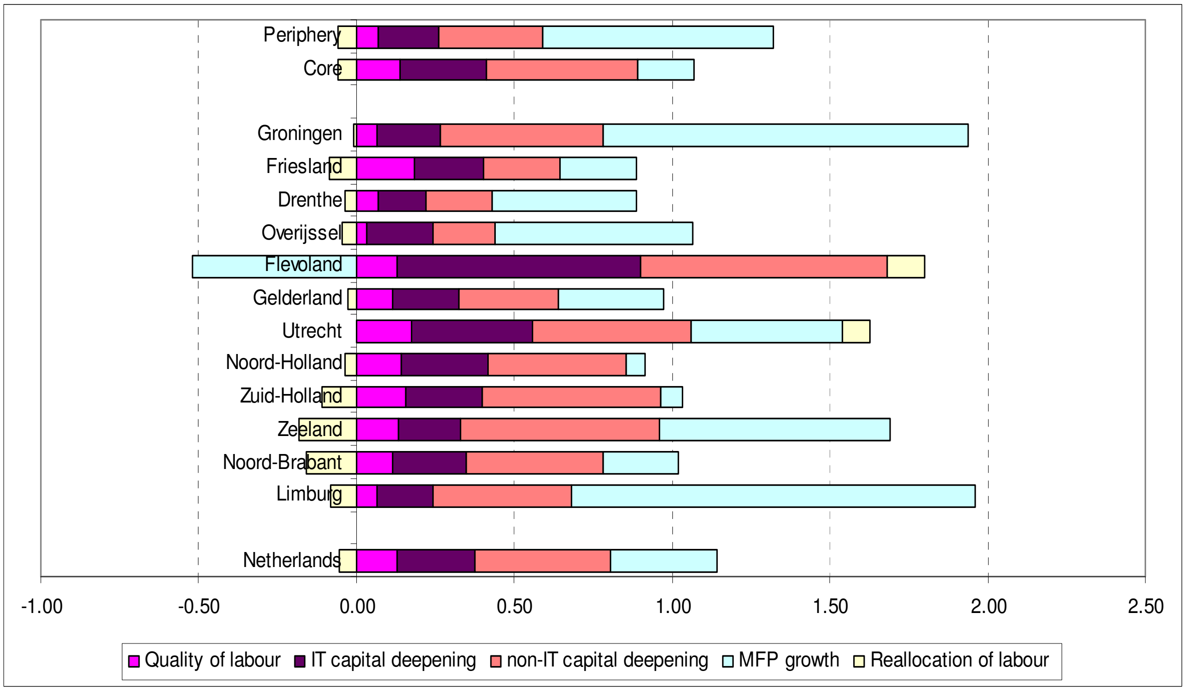
Figure 5 presents an overview of the sources of aggregate productivity growth between 1995-2002 in The Netherlands and each of the twelve provinces under consideration. Table A2 in Appendix 1 presents an overview of all the sectoral and provincial results. The first phenomenon that catches the eye is the divergent pattern for the province of Flevoland. This is the sole region with a negative MFP growth rate, while the contribution of IT capital deepening to productivity growth is quite large. That is why we first need to elaborate on this province.

4.1.The special case of Flevoland
Flevoland is the latest province of The Netherlands, established in 1986, and composed of newly conquered land from the IJsselmeer (see also Appendix 3, figure A1). This means that growth in this province has the character of catching-up to the Dutch average, both in growth of population, employment and output. It is further characterised by high levels of commuting, especially to the so-called Randstad area. In 2001 more than 60,000 workers, i.e. 41% of the working population in Flevoland, were commuting out to the Randstad, i.e. Noord-Holland, Zuid-Holland and Utrecht.

On the other hand, the build-up from scratch of this province implied that use could be made of state of the art technology. At the same time a negative commuting balance implies a relatively low GDP. Both issues lead to the fact that Flevoland has the highest share of IT investment in GDP of all provinces (Appendix 2). It also explains why Flevoland has such a large contribution of IT capital deepening to productivity growth compared to other provinces, for which mainly the financial and business service sector is responsible (Appendix 1). However, this exact same industry is also largely responsible for the negative MFP-growth rate in Flevoland.

Hence, the combination of advert patterns of (catch-up) growth, commuting and consequently a relatively low GDP levels in combination with high shares of IT investment may give rise to this adverse pattern of growth contributions in Flevoland.

Figure 5. Sources of labour productivity growth in The Netherlands at regional level, 1995-2002.



4.2.The other provinces

MFP-growth

For the other eleven provinces the contribution of the different sources to productivity growth is roughly comparable. MFP growth is the largest contributor to these growth rates. Only in Noord-Holland, Zuid-Holland, Noord-Brabant and in Friesland its impact is relatively small. In fact the lagging MFP-growth in these provinces is the main reason for their low productivity growth rates.

This low MFP-growth is particularly due to the financial and business sectors in all three provinces, but also MFP-growth in agriculture in Noord-Brabant and MFP-growth in manufacturing in Zuid-Holland contribute substantially (see Appendix 1). Agriculture in Noord-Brabant is traditionally dominated by factory farming of pigs. The negative MFP-growth in agriculture of Noord-Brabant primarily refers to the period 1996/1997, when this province was struck by the pig fever. One industry that may account for the negative MFP-growth in manufacturing in Zuid-Holland is the oil refinery sector, which is quite dominant and is known to have a negative MFP-contribution from Inklaar et al (see also Appendix 1 where the detailed industry results from Inklaar et al. for The Netherlands between 1995-2000 are replicated in table A1).

The negative MFP-growth rates for financial and business services in these three provinces clearly correspond to the negative MFP-growth rates for financial intermediation found by Inklaar et al. They also report a large positive contribution to Dutch MFP-growth of wholesale trade. In all provinces we find that the composite trade and restaurant sector has indeed relatively strong MFP-growth rates, particularly in Utrecht. Since Utrecht is the province with the highest workers in wholesale trade, this corroborates Inklaar et al. as well.[6]

The highest positive contribution of MFP-growth to productivity growth is found in Groningen and Limburg. In Groningen this is the result of the transport and communication sector and in Limburg this is manufacturing. Transport and communication in Groningen is dominated by communication.[7] Table A1 corroborates that national MFP-growth in communication is strong and positive. Therefore the large contribution of MFP-growth to labour productivity growth in Groningen can largely be attributed to communication. For MFP-growth in Limburg the same can be said of the chemical industry.

IT capital deepening

Figure 5 shows that the contribution of IT capital deepening (growth of IT capital per hour worked) has been positive in all regions. Apart from Flevoland, its contribution was particularly large in Utrecht and Noord-Holland, which was a result of financial and business services. In fact this sector made by far the highest contribution to IT capital deepening in all provinces, except for Drenthe (social/non-market services) and Zeeland (manufacturing and social/non-market services). Financial and business services are also the ones with a high contribution of IT capital deepening according to Inklaar et al. (table A1).

Financial and business services are known to be intensive users of IT capital, which is an important explanation for their productivity performance (van Ark et al., 2002a; Appendix A). Another IT using industry that has a high contribution of IT capital deepening nation-wide is wholesale trade (Table A1). The contribution of composite trade and hotels is relatively high in provinces that also have a high share of wholesaling, as in Utrecht, Noord-Holland and Noord-Brabant. In these provinces it is therefore likely that IT capital deepening in wholesale trade has made a substantial contribution to productivity growth.

Hence, IT capital deepening in IT using services industries has made important contributions to productivity growth in all provinces, but particularly in the central and southern ones. This corroborates the importance of IT use as carrier of productivity growth.

Non-IT capital deepening

Just like IT capital deepening, figure 5 also shows that non-IT capital deepening (growth of non-IT capital per hour) has generally made a positive contribution to productivity growth. The overall contribution of non-IT capital deepening is relatively low in the provinces of Friesland, Drenthe and Overijssel, despite the fact that the contribution of manufacturing to non-IT capital deepening in Drenthe and Overijssel is quite large compared to other regions. In Friesland the contribution of manufacturing is low in absolute terms for all industries. Another important sector in this respects are social and non-market services that generate a negative contribution of non-IT capital deepening to productivity growth.

In most provinces the manufacturing sector is the major contributor. The highest contribution is found in Limburg, Zeeland and Groningen, who all have a high share of capital-intensive chemical industry. According to Inklaar et al. in the chemical industry non-IT capital deepening indeed makes a strong positive contribution to productivity growth (Table A1). Only in Friesland and the three Randstad-provinces of Utrecht, Noord-Holland and Zuid-Holland the financial and business services sector has the largest contribution. Friesland has

[6] Provincial employment data by industry of 2002 show that in Utrecht 35% of all employees in the composite trade and restaurant sector (ISIC 50-55) work in wholesale trade (ISIC 51) against 29% nation-wide (source: Statistics Netherlands, EWL)

[7] Provincial employment data by industry of 2001 show that 47% of all employees in transport and communication (ISIC 60-64) in Groningen are in fact working in communications (ISIC 64) against 28% nation-wide (source: Statistics Netherlands, EWL, REJ)

an overrepresentation of financial services, while both financial and business services are dominant in the Randstad-provinces.

Labour quality
The overall contribution of labour quality to productivity growth is also positive in all provinces, but is relatively high in the Randstad-provinces of Utrecht, Noord-Holland a Zuid-Holland and relatively low in the peripheral provinces of Overijssel, Drenthe, Groningen and Limburg. In the economic core regions, all industries contribute positively to the effect of labour quality, particularly financial and business services. In fact the same is true for the peripheral regions, but to a lesser extent. Only in Overijssel financial and business services do not contribute to the effect labour quality, instead manufacturing is the dominant industry.

Reallocation of hours work
Equation (16) derives the reallocation of employment, which shows that the movement of labour from low-productivity-level industries to high-productivity-level industries will raise productivity even when the actual productivity growth rates in both industries is zero. In other words, this term is positive when industries in an above average labour productivity level show positive employment growth or likewise with below-average productivity levels have falling employment. Negative values show that high productivity industries and industry employment growth do not go hand in hand.

Figure 5 shows that in almost all provinces this reallocation term is negative. This means that the expansion of employment in the second half of the 1990's in these provinces mainly took place in the less productive sectors, or that employment decline took place mainly in high productive sectors. Only in Utrecht and Flevoland the opposite occurred. Between 1995 and 2002 all provinces witnessed strong increases in employment. In many cases the effect of the employment rise in high productive jobs, like in financial institutions and knowledge based intensive services (KIBS), was counteracted by an even larger rise in less productive industries, like health care, cleaning, security, the hotel business and temporary work agencies.

The positive reallocation in Flevoland had to do with the catch-up growth mentioned earlier, because employment growth in every industry of this province was the highest of all. Utrecht, on the other hand, was the only province with a clear employment rise in high productive industries like communication, financial institutions and KIBS, whereas the rise in less productive industries, like health care, was very modest.

4.3. Peripheral versus core regions
Figure 5 also shows the sources of labour productivity growth by a composition of provinces into an economic core and a peripheral region. The core region is identified as all provinces that roughly fall within a 100-kilometre radius of the (rectangle of) core cities of the Randstad formed by Utrecht, Amsterdam, Roterdam and The Hague. All provinces with a distance of more than 100 kilometres of these cities are labelled peripheral regions. Table 1 give a division of provinces by core and peripheral regions.

Table 1. Subdivision of provinces in core and peripheral regions

Core regions	Peripheral regions
Noord-Holland	Groningen
Zuid-Holland	Friesland
Zeeland	Drenthe
Noord-Brabant	Overijssel
Gelderland	Limburg
Flevoland	

Figure 5 shows that labour productivity growth in the core regions has been lower than in the periphery. It also shows why this is the case. The core regions do have a slightly higher effect of labour quality and of IT and non-IT capital deepening, but by far a lower contribution of MFP-growth. This low rate of growth of MFP does correspond to what Inklaar et al (2003) report as the main source for the Dutch productivity slowdown in the second half of the 1990's. Table A2 of Appendix 1 shows that this low MFP-growth in the core region is a result of relatively low MFP-growth rates in agriculture, transport and communication an to a slightly lesser extent in manufacturing and financial and business services. Only MFP-growth in non-market services was larger in the core region than in the periphery. Notice that in both regions construction and the financial and business service sector had negative MFP-growth rates, which corresponds to Inklaar et al. (2003) (see also Table A1).

Hence, the lagging MFP-growth rate is a phenomenon that occurred particularly in the core region, mainly Noord-Holland and Zuid-Holland and in Noord-Brabant. These three provinces account for 55% of the entire Dutch GDP, so they have a large weight in aggregate Dutch productivity growth. This also means that the slowdown in productivity growth for the period 1995-2002 can largely be attributed to these core regions, particularly due to lagging MFP-growth in agriculture, transport and communication and large negative MFP-growth in financial and business services.

4.4. Policy relevancy

It may come as a surprise that particularly the core regions, which are the designated areas to which the Dutch government has assigned specific policy proposals, are the main cause for the slowdown in Dutch productivity growth. The arguments to focus on these core regions are that they are high potential, high productivity areas with positive agglomeration effects.[8] These policy plans fall within the framework of achieving a higher productivity growth rate than is currently the case (see introduction and Broersma and van Dijk, 2005).

Based on the results of the current growth accounting exercise two types of measures can be thought of to get the productivity growth rate of The Netherlands back on track. One is to stimulate the lagging contribution of labour quality and IT capital deepening in the peripheral region. Labour quality growth in the peripheral regions has a low contribution in all sectors, apart from financial and business services. IT capital deepening in the periphery is lower is all sectors compared to the core region.

The overall level of education of the labour force in the periphery is lower than in the core region (see Table A3 in Appendix 2). The same is true for the share of IT investments in value added (see Tables A4 and A5 in Appendix 2). Enhancing the use of IT equipment in all industries of the peripheral region may enlarge its contribution labour productivity growth.

The other measure is to stimulate MFP-growth in the core region, because this seems to be the major factor that is responsible for the Dutch productivity slowdown in the latest years. The contribution of MFP-growth to labour productivity growth is negative in financial and business services and in construction. It is positive, but relatively low in agriculture, manufacturing and non-market services. The problem of trying to raise MFP-growth is the fact that it is composed of a myriad of different aspects, ranging from R&D and innovation to cultural differences and measurement errors.

[8] See Dutch Ministry of Economic Affairs, "Pieken in de Delta" (in Dutch), the Traffic Ministry, "Nota Mobiliteit" (in Dutch) and the Ministry of Environmental Planning, "Nota Ruimte" (in Dutch).

R&D and innovation are known to be relatively high in the core regions (Broersma and Oosterhaven, 2004), so it is unlikely that they can explain their lagging MFP-growth. Another important difference between the core and periphery that has recently drawn attention is a negative agglomeration effect in the core regions with respect to productivity growth. Broersma and Oosterhaven (2004) found that an increase in job density of 1%, say, leads to a slowdown in labour productivity growth of about 0.5%. The main reason being congestion and lack of space. The core regions are known to have a substantially higher job density and also much higher traffic congestion than the periphery. The Dutch Traffic Ministry has recently estimated the direct effect of the latter on loss of output to be almost 1 billion euro. In the core regions, in which this congestion is concentrated, this implies about 6% less growth of GDP due to congestion. Given the growth rate of employment this means that productivity growth in the core regions could be 6% higher.

This seems a minor influence of in fact less than 0.1 percentage point productivity growth, but this is an annual lag so it recurs every year, given the level of congestion. Second, the deteriorating effect of congestion on productivity in the future should not be thought of lightly. Next to the direct effect of loss of production, there are also indirect effects, like uncertainty about travel time that might divert companies away from settling in The Netherlands. These indirect effects might be more far reaching.

Other aspects that may drive regional differences in MFP-growth are for instance work effort, local/provincial regulation, social-cultural aspects and the like. These are obviously broad measures that do affect business operations beyond the traditional production factors labour and capital by type. A major drawback is that they are not observed as such and can be only be approximated by proxy indicators. This measurement problem already pertains to the national level, so for region indicators it is even more acute. Nevertheless in the next section we will approximate these aspects by a number of different explanatory variables for regional MFP-growth.

Unfortunately we cannot examine the effect of wage growth moderation on non-IT capital deepening. The main reason for this is the fact that regional wage rates in The Netherlands basically grow at the same rate each year, since there are no region-specific wage negotiations. Furthermore, our sample period is too short the examine whether the contribution of non-IT capital deepening has increased or decreased when the first and second half of the 1990’s are compared. Nevertheless, based on Inklaar et al (2003) the effect of non-IT capital deepening on the deceleration of productivity growth in The Netherlands is far less important that MFP-growth. That means that the effect of wage growth moderation in The Netherlands did not have a large negative impact on the slowdown in productivity growth.

Finally, another important aspect of this growth accounting exercise is the fact that in many regions the surge in employment of the second half of the 1990’s took place mainly in low productivity sectors. This reallocation effect also contributed to the slowdown of productivity growth in The Netherlands in recent years.

4.5. Explaining regional MFP-growth

MFP-growth is the part of productivity growth that cannot be attributed to changes in labour quality and capital assets, IT and non-IT capital. Economic theory predicts a number of variables to influence MFP-growth. Table 2 provides an overview of explanatory variables that are available at the regional level, the kind of theory the explanation stems from and the main reference on this topic. Appendix 3 shows how these indicators are constructed using regional statistical information of The Netherlands.

Table 2. Indicators that can be used to explain MFP-growth

Indicator	Theoretical underpinning	Reference
Innovation/R&D	Innovation literature	Griliches, 1995
Job density/congestion	Agglomeration effect, growth literature	Gleaser, 1992
Labour effort/work ethic	Productivity literature	Deans, 1972; Green, 1999
Regulatory burden (product market	Productivity literature	Nicoletti/Scarpetta, 2003
Regulatory burden (labour market)	Productivity literature	Nicoletti/Scarpetta, 2003

The economic literature on innovation predicts that it is not so much the growth rate of innovation or R&D that affects the growth of productivity, but rather that (the level or share of) innovation (or R&D) itself stimulates productivity growth. Growing innovation will then lead to an acceleration of productivity growth. That is the main reason why the Dutch government makes major policy efforts to stimulate innovations in order to get productivity growth on a higher growth track (see figure 1).

In fact there are ample arguments that the level of the indicators mentioned in Table 2 stimulate productivity growth and not so much the level of productivity. Only in case of agglomeration effects the level of agglomeration may also affect the level of productivity (Ciccone and Hall, 1996). The regulation argument is on the other hand often used to explain difference in productivity growth (Winston, 1993, 1998).

These arguments lead to the specification of a model we will use to explain regional MFP-growth in The Netherlands. Since none of the indicators can be distinguished at both industry and regional level, we model the regional economy-wide MFP-growth only. We use pooled regional data for the period 1996/1997 through 2001/2002 for estimation.

$$\Delta \log mfp_{i,t} = \mu_{0,i} + \sum_j \mu_{i,j} I_{i,j} \tag{19}$$

where $I_{i,j}$ refers to indicator *j* for region *i*, *mfp* stems from equation (17). Table 3 presents the preferred estimation results for this equation using OLS based on heteroscedasticity and autocorrelation robust covariance estimates. The construction, definition and sources of the variables of this model are presented in Appendix 3. Appendix 3 also shows the extent to which these indicators are correlated amongst each other and gives the initial specifications for (19) based on these correlations. Given our indicators, table 3 shows that equation (19) is best estimated with regional fixed effect dummies to grasp all influences on MFP-growth that were not captured by the indicators I_j for each region. Congestion, measured as the number of cars per kilometre of road, and labour effort, measured as the unemployment-vacancy ratio, are the explanatory variables with a significant impact on MFP-growth.

Notice that in this case R&D does not affect MFP-growth in this case. This comes as no surprise since high R&D regions are located in the core regions, while these regions have a relatively low MFP-growth. One possible explanation for this is the fact that R&D results more in process innovations than product innovations. Process innovations are more likely to be embodied in the production factors, especially in capital, then product innovations. This would explain why the core regions had slightly higher effects of IT and non-IT capital deepening and of labour quality. MFP-growth, which is all about disembodied technical progress, is on the other hand, quite low in the core regions. Part of this relatively low disembodied technical progress is thus explained by production loss due to traffic congestion and part is due to a weakly lower work ethic (labour effort) in the core regions.

Table 3. Estimation results of (19) with preferred explanatory indicators.

	General model			Simplified model		
	All regions	Core	Periphery	All regions	Core	Periphery
Intercept	8.80	13.4	6.80	7.80	8.72	0.44
	(3.20)	(3.59)	(1.21)	(5.88)	(6.61)	(0.97)
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R&D-share	-0.27	-0.59	0.08			
	(-0.52)	(-1.11)	(0.10)			
Car density	-0.15	-0.20	-0.13	-0.14	-0.15	
	(-4.75)	(-6.04)	(-1.27)	(-6.08)	(-7.49)	
Labour effort	0.07	-0.13	0.15	0.09		0.22
	(1.36)	(-1.32)	(1.970	(1.80)		(4.70)
Adjusted R^2	0.39	0.37	0.44	0.40	0.37	0.47
Residual se	0.89	0.87	0.85	0.88	0.87	0.83
N	72	42	30	72	42	30

Note: *t*-values between brackets are based on the Newey-West covariances robust for heteroscedasticity and autocorrelation.

5. Concluding remarks

Regional differences in labour productivity growth in The Netherlands are analysed in a regional growth accounting. Labour productivity growth appears to be higher in the peripheral regions of the North and South than in the economic core regions. The main reason for this lagging growth performance is the slow MFP-growth in these core regions. This lagging position is particularly caused by the financial and business sector. The contribution of labour quality, IT and non-IT capital deepening to productivity growth is, however, larger in the core regions that in the periphery, but cannot counteract the lower impact of MFP-growth. Although difficult to pinpoint, we found that the slow MFP-growth in the core regions is partly related to the high and rising traffic congestion and shortage of space and partly to lower work effort in these regions, compared to the periphery.

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Appendix 1. Results of growth accounting

Table A1 presents a summary of the results of the growth accounting exercise for The Netherlands by Inklaar et al. (2003), using industry data.
Table A2 presents the results of the growth accounting exercise of the current paper performed on regional industry data for The Netherlands.

Table A1. Summary result of growth accounting of labour productivity growth in The Netherlands 1995-2000 drawn from Inklaar et al. (2003)

Industry	Industry contribution to aggregate labour productivity growth	Contribution to aggregate labour productivity growth of			
		labour quality growth	IT capital deepening	non-IT capital deepening	MFP-growth
Agriculture, forestry and fishing	0.08	0.00	0.00	0.03	0.05
Mining and quarrying	0.09	0.00	0.01	0.10	-0.03
Food products	0.05	0.01	0.02	0.02	0.01
Textiles, clothing and leather	0.04	0.00	0.00	0.00	0.03
Wood products	0.01	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.09	0.00	0.02	0.02	0.04
Petroleum and coal products	-0.04	0.00	0.00	0.01	-0.06
Chemical products	0.10	0.00	0.00	0.05	0.05
Rubber and plastics	0.03	0.00	0.00	0.00	0.02
Non-metallic mineral products	0.03	0.00	0.00	0.01	0.02
Metal products	0.04	0.00	0.01	0.01	0.02
Machinery	0.05	0.00	0.01	0.00	0.03
Electrical and electronic equipment and instruments	-0.03	0.00	0.02	0.00	-0.06
Transport equipment	0.04	0.00	0.00	-0.01	0.05
Furniture and miscellaneous manufacturing	0.03	0.00	0.00	0.00	0.02
Electricity, gas and water	0.07	0.00	0.01	0.08	-0.02
Construction	0.01	0.00	0.03	0.03	-0.03
Wholesale trade	0.46	0.00	0.08	0.01	0.37
Retail trade	0.09	0.00	0.02	0.01	0.05
Hotels and restaurants	0.02	0.00	0.00	-0.01	0.03
Transport and storage	0.16	0.01	0.01	0.01	0.12
Communication	0.21	0.01	0.03	0.04	0.13
Financial intermediation	0.00	0.03	0.19	0.02	-0.24
Business services	0.14	0.05	0.07	-0.03	0.05
Social and personal services	-0.01	-0.01	0.01	-0.02	0.01
Non-market services	0.11	0.02	0.04	0.01	0.04
Reallocation of hours	-0.34				
Total economy	1.52	0.14	0.61	0.41	0.70

Table A2. Results of growth accounting of labour productivity growth by region and industry, The Netherlands, 1995-2002

Source of productivity growth	Industry	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland	Utrecht	Noord-Holland	Zuid-Holland	Zeeland
Labour productivity	Agriculture and fishery	0.14	0.22	0.20	0.04	0.28	0.08	0.02	0.02	0.00	0.10
Growth	Manufacturing and utilities	0.46	0.26	0.34	0.34	0.05	0.23	0.21	0.26	0.19	1.11
	Construction	0.01	0.00	-0.07	-0.03	-0.01	-0.02	0.00	-0.02	0.00	-0.01
	Trade, hotels and restaurants	0.20	0.21	0.23	0.37	0.37	0.30	0.64	0.46	0.33	0.38
	Transport and communication	0.92	0.15	0.05	0.26	0.14	0.09	0.49	0.33	0.49	0.26
	Financial and business services	0.33	0.19	0.14	0.10	0.41	0.18	0.05	-0.11	-0.04	0.03
	Social and non-market services	-0.10	-0.13	0.00	-0.02	-0.08	0.10	0.12	-0.02	0.06	-0.18
	Total economy	1.93	0.80	0.85	1.02	1.28	0.95	1.63	0.88	0.93	1.51
	Reallocation of hours	-0.01	-0.09	-0.03	-0.04	0.12	-0.03	0.09	-0.03	-0.11	-0.18
Quality of labour	Agriculture and fishery	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacturing and utilities	0.02	0.03	-0.05	0.03	-0.02	0.04	0.03	0.02	0.01	0.02
	Construction	-0.01	-0.02	0.03	0.02	0.00	0.01	0.03	0.00	0.00	0.00
	Trade, hotels and restaurants	0.02	0.04	-0.03	-0.01	0.12	0.00	0.03	0.05	0.01	0.03
	Transport and communication	-0.02	-0.01	0.02	0.01	0.03	0.01	0.00	0.01	0.02	0.00
	Financial and business services	0.09	0.13	0.06	0.00	0.05	0.05	0.08	0.06	0.08	0.06
	Social and non-market services	-0.03	0.01	0.04	-0.01	-0.05	0.00	0.00	0.00	0.04	0.03
	Total economy	0.07	0.19	0.07	0.03	0.13	0.11	0.18	0.14	0.16	0.13
IT contribution	Agriculture and fishery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Manufacturing and utilities	0.03	0.02	0.03	0.05	0.03	0.02	0.03	0.03	0.04	0.07
	Construction	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00
	Trade, hotels and restaurants	0.02	0.02	0.02	0.03	0.06	0.04	0.07	0.06	0.03	0.02
	Transport and communication	0.03	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.03	0.01
	Financial and business services	0.08	0.12	0.04	0.07	0.62	0.09	0.23	0.14	0.10	0.03
	Social and non-market services	0.04	0.05	0.05	0.04	0.06	0.04	0.04	0.03	0.04	0.06
	Total economy	0.20	0.22	0.15	0.21	0.78	0.21	0.38	0.27	0.24	0.19

Non-IT contribution	Agriculture and fishery	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01
	Manufacturing and utilities	0.31	0.06	0.16	0.17	-0.02	0.21	0.08	0.10	0.20	0.41
	Construction	0.01	0.02	0.02	0.02	-0.03	0.02	0.01	0.01	0.02	0.02
	Trade, hotels and restaurants	0.03	-0.01	0.01	0.04	-0.09	0.03	0.04	0.00	0.06	0.07
	Transport and communication	0.23	0.03	0.00	0.04	-0.05	0.03	0.03	0.13	0.15	0.17
	Financial and business services	0.07	0.27	0.10	0.02	1.09	0.11	0.40	0.29	0.23	0.05
	Social and non-market services	-0.13	-0.13	-0.09	-0.10	-0.14	-0.09	-0.04	-0.09	-0.09	-0.09
	Total economy	0.52	0.24	0.21	0.20	0.78	0.31	0.50	0.44	0.57	0.63
MFP-growth	Agriculture and fishery	0.14	0.22	0.20	0.04	0.27	0.07	0.02	0.01	0.00	0.09
	Manufacturing and utilities	0.09	0.15	0.20	0.09	0.06	-0.04	0.08	0.12	-0.06	0.61
	Construction	0.01	-0.01	-0.14	-0.08	0.01	-0.05	-0.05	-0.03	-0.03	-0.03
	Trade, hotels and restaurants	0.14	0.16	0.22	0.31	0.29	0.24	0.51	0.35	0.22	0.26
	Transport and communication	0.68	0.13	0.03	0.20	0.14	0.04	0.44	0.19	0.30	0.09
	Financial and business services	0.09	-0.34	-0.05	0.02	-1.35	-0.07	-0.65	-0.61	-0.44	-0.11
	Social and non-market services	0.02	-0.07	0.00	0.05	0.05	0.15	0.13	0.03	0.08	-0.17
	Total economy	1.16	0.24	0.45	0.62	-0.52	0.34	0.48	0.06	0.07	0.73

Table A2 (continued)

		Noord-Brabant	Limburg	Netherlands	Core	Periphery
Labour productivity growth	Agriculture and fishery	-0.15	-0.01	0.37	-0.21	1.81
	Manufacturing and utilities	0.47	1.17	1.75	1.56	2.30
	Construction	-0.04	-0.04	-0.20	-0.15	-0.38
	Trade, hotels and restaurants	0.31	0.30	2.20	2.24	2.00
	Transport and communication	0.16	0.51	4.14	3.81	5.62
	Financial and business services	0.27	0.16	0.37	0.21	1.26
	Social and non-market services	0.00	-0.13	0.02	0.12	-0.32
	Total economy	0.86	1.88	1.14	1.01	1.47
	Reallocation of hours	-0.16	-0.08	-0.05	-0.06	-0.06
Quality of labour	Agriculture and fishery	0.00	0.00	-0.02	0.00	-0.06
	Manufacturing and utilities	0.04	0.04	0.12	0.14	0.08
	Construction	0.01	0.00	0.13	0.15	0.06
	Trade, hotels and restaurants	0.02	0.00	0.11	0.13	0.03
	Transport and communication	0.01	0.00	0.10	0.12	0.02
	Financial and business services	0.05	0.04	0.32	0.31	0.39
	Social and non-market services	-0.02	-0.01	0.02	0.04	-0.02
	Total economy	0.12	0.07	0.13	0.14	0.07
IT contribution	Agriculture and fishery	0.00	0.00	0.01	0.01	0.01
	Manufacturing and utilities	0.04	0.04	0.17	0.17	0.15
	Construction	0.01	0.01	0.11	0.11	0.10
	Trade, hotels and restaurants	0.05	0.03	0.25	0.25	0.21
	Transport and communication	0.01	0.01	0.18	0.18	0.15
	Financial and business services	0.08	0.05	0.57	0.58	0.54
	Social and non-market services	0.04	0.04	0.15	0.14	0.17
	Total economy	0.23	0.18	0.25	0.27	0.19

Non-IT contribution	Agriculture and fishery	0.00	0.00	0.05	0.04	0.09
	Manufacturing and utilities	0.21	0.46	0.96	0.98	0.92
	Construction	0.03	0.02	0.24	0.22	0.30
	Trade, hotels and restaurants	0.00	0.04	0.17	0.16	0.19
	Transport and communication	0.03	-0.02	0.97	1.04	0.63
	Financial and business services	0.24	0.06	1.03	1.04	0.92
	Social and non-market services	-0.08	-0.13	-0.37	-0.36	-0.38
	Total economy	0.43	0.44	0.43	0.48	0.33
MFP-growth	Agriculture and fishery	-0.15	-0.01	0.33	-0.27	1.77
	Manufacturing and utilities	0.18	0.62	0.50	0.27	1.15
	Construction	-0.09	-0.06	-0.68	-0.63	-0.84
	Trade, hotels and restaurants	0.24	0.23	1.67	1.69	1.57
	Transport and communication	0.12	0.51	2.89	2.46	4.81
	Financial and business services	-0.11	0.01	-1.55	-1.72	-0.59
	Social and non-market services	0.05	-0.03	0.22	0.30	-0.08
	Total economy	0.24	1.28	0.34	0.18	0.73

Note: mining and real estate were not included.

Appendix 2. Labour quality and IT intensity

As background information this Appendix presents the share of workers by education level, industry and region in The Netherlands. Its shows in what regions and industries persons of a certain education level are employed (Table A3).
Tables A4 and A5 provide information on the share of investment of IT and non-IT equipment in value added by industry and region. It shows the IT (and non-IT) intensity by industry and region.

Table A3. Shares of employed labour force (%) by level of education (low/intermediate/high) by region and industry, The Netherlands 1995-2002

	Groningen			Friesland			Drenthe			Overijssel		
Industry	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher
Agriculture and fishery	35.1	55.8	9.0	44.2	50.5	5.3	41.7	55.6	2.7	41.5	54.3	4.2
Manufacturing and utilities	45.0	44.7	10.2	45.1	44.6	10.3	44.7	45.2	10.1	41.3	46.0	12.8
Construction	44.1	50.7	5.2	46.0	50.0	4.0	48.1	47.2	4.8	43.2	51.8	5.0
Trade, hotels and restaurants	34.3	56.0	9.7	34.5	59.2	6.3	36.0	57.3	6.7	36.6	55.4	8.0
Transport and communication	40.0	42.5	17.4	50.6	40.3	9.2	46.8	43.8	9.3	44.6	48.9	6.4
Financial and business services	20.4	43.7	35.9	20.1	47.0	32.9	20.4	50.2	29.4	16.4	46.5	37.1
Social and non-market services	13.4	42.3	44.3	14.2	47.7	38.2	16.4	49.1	34.6	14.0	44.6	41.4
Total economy	28.1	46.0	25.9	30.4	49.0	20.6	31.1	49.8	19.1	29.7	48.3	22.0

Table A3. (continued)

	Flevoland			Gelderland			Utrecht			Noord-Holland		
Industry	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher
Agriculture and fishery	31.7	59.1	9.1	44.0	50.4	5.6	47.3	50.3	2.4	44.1	50.7	5.1
Manufacturing and utilities	41.3	45.6	13.2	43.7	41.9	14.5	35.1	41.9	23.0	34.0	46.3	19.7
Construction	50.2	48.0	1.8	45.2	49.7	5.0	42.8	48.9	8.3	41.4	51.7	7.0
Trade, hotels and restaurants	43.0	46.9	10.2	37.9	52.1	10.0	35.2	48.3	16.5	37.9	47.4	14.7
Transport and communication	43.4	45.1	11.5	47.6	42.2	10.2	38.8	40.0	21.2	33.4	44.9	21.8
Financial and business services	22.2	42.8	35.0	16.8	42.1	41.2	15.5	35.9	48.6	17.2	37.2	45.6
Social and non-market services	18.2	44.7	37.1	15.2	40.8	43.9	12.8	34.5	52.7	14.2	38.2	47.6
Total economy	30.7	45.8	23.5	29.9	44.4	25.7	23.7	39.5	36.8	25.4	42.3	32.3

Table A3. (continued)

	Zuid-Holland			Zeeland			Noord-Brabant			Limburg		
Industry	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher
Agriculture and fishery	56.8	38.6	4.7	48.3	49.9	1.8	41.1	53.4	5.5	43.8	49.8	6.4
Manufacturing and utilities	38.8	44.6	16.6	31.8	53.4	14.8	36.9	43.2	19.9	41.5	43.7	14.7
Construction	44.2	47.1	8.7	44.5	50.5	5.0	45.9	46.8	7.4	49.7	45.4	4.8
Trade, hotels and restaurants	41.9	46.6	11.5	44.5	48.9	6.6	35.5	53.1	11.4	39.1	51.6	9.3
Transport and communication	38.8	44.3	17.0	45.7	40.0	14.3	44.1	43.9	12.0	47.1	41.2	11.8
Financial and business services	18.8	41.0	40.2	20.5	49.6	29.8	17.7	41.0	41.3	18.4	43.1	38.5
Social and non-market services	16.8	39.7	43.6	18.1	47.3	34.6	15.5	42.2	42.4	16.6	43.5	39.9
Total economy	29.1	42.6	28.4	31.7	49.0	19.4	29.2	45.2	25.6	31.6	45.2	23.2

Table A3. (continued)

	Netherlands				Core regions			Peripheral regions		
Industry	Lower	Inter-mediate	Higher		Lower	Inter-mediate	Higher	Lower	Inter-mediate	Higher
Agriculture and fishery	45.4	49.4	5.2		46.8	48.1	5.0	42.0	52.6	5.4
Manufacturing and utilities	39.3	44.3	16.3		37.9	44.1	18.0	42.7	44.8	12.5
Construction	44.8	48.7	6.5		44.2	48.6	7.1	46.0	49.1	4.8
Trade, hotels and restaurants	38.2	50.5	11.4		38.6	49.1	12.3	36.7	55.1	8.2
Transport and communication	40.8	43.6	15.6		39.6	43.6	16.8	45.7	43.7	10.6
Financial and business services	17.9	40.8	41.4		17.6	39.7	42.7	18.7	45.2	36.1
Social and non-market services	15.3	40.9	43.8		15.3	39.7	44.9	14.9	45.0	40.1
Total economy	28.6	44.2	27.2		28.0	43.3	28.8	30.3	47.3	22.4

Table A4. Investment in IT assets as percentage of value added by industry and region, The Netherlands 1995-2002

Industry	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland	Utrecht	Noord-Holland	Zuid-Holland	Zeeland	Noord-Brabant	Limburg
Agriculture and fishery	0.7	0.5	0.6	0.7	0.8	0.9	0.8	0.6	0.6	1.0	1.1	0.9
Manufacturing and utilities	1.3	0.6	0.8	1.4	2.1	0.7	1.3	1.3	1.2	1.2	0.9	1.0
Construction	0.5	0.5	0.6	0.5	0.5	0.4	0.7	0.4	0.7	0.4	0.5	0.6
Trade, hotels and restaurants	0.9	0.8	1.0	1.0	1.7	1.4	1.0	1.1	0.9	0.8	1.6	1.1
Transport and communication	0.7	0.7	0.7	1.6	1.1	1.1	1.0	1.7	1.3	0.7	1.1	1.2
Financial and business services	5.4	4.1	2.5	4.8	10.6	4.3	3.7	3.4	3.4	3.2	3.6	2.9
Social and non-market services	2.2	2.4	2.5	2.5	3.5	2.4	2.5	2.2	2.3	2.4	2.9	2.2
Total economy	2.0	1.7	1.6	2.0	4.3	1.9	2.2	2.0	1.9	1.5	1.9	1.6

Table A4. (continued)

Industry	Netherlands	Core	Periphery
Agriculture and fishery	0.7	0.8	0.7
Manufacturing and utilities	1.1	1.1	1.1
Construction	0.6	0.6	0.5
Trade, hotels and restaurants	1.2	1.2	1.0
Transport and communication	1.3	1.4	1.1
Financial and business services	3.7	3.7	3.9
Social and non-market services	2.4	2.4	2.3
Total economy	1.9	2.0	1.8

Note: all data are net of mining and real estate

Table A5. Investment in non-IT assets as percentage of value added by region and industry, The Netherlands 1995-2002

Industry	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland	Utrecht	Noord-Holland	Zuid-Holland	Zeeland	Noord-Brabant	Limburg
Agriculture and fishery	25.8	19.9	21.3	25.1	29.4	34.9	28.6	23.7	21.4	36.4	39.8	32.0
Manufacturing and utilities	21.2	13.1	14.7	13.8	17.0	15.8	14.6	14.1	15.3	17.6	13.9	18.7
Construction	5.8	6.2	5.8	6.2	4.8	6.7	7.5	6.3	7.4	6.3	6.1	5.9
Trade, hotels and restaurants	11.3	10.2	10.3	10.3	9.9	9.9	8.3	8.6	10.4	11.0	9.6	10.4
Transport and communication	37.2	28.1	22.5	27.9	27.8	27.5	28.3	31.1	35.8	32.7	28.9	28.6
Financial and business services	11.7	18.7	14.4	10.5	42.4	13.6	15.4	15.4	17.2	14.6	19.8	12.4
Social and non-market services	13.1	14.3	15.6	14.9	21.9	14.6	14.7	13.2	13.9	14.3	17.2	13.6
Total economy	17.3	14.9	14.3	13.8	24.1	14.7	14.5	14.9	16.3	16.9	15.8	15.8

Table A5. (continued)

Industry	Netherlands	Core	Periphery
Agriculture and fishery	27.4	28.5	24.8
Manufacturing and utilities	15.3	14.8	16.6
Construction	6.6	6.7	6.0
Trade, hotels and restaurants	9.6	9.5	10.4
Transport and communication	31.6	31.9	30.1
Financial and business services	16.3	16.9	13.0
Social and non-market services	14.5	14.6	14.2
Total economy	15.5	15.6	15.2

Note: all data are net of mining and real estate.

Appendix 3. Data, sources and definitions

Introduction

In this appendix the sources, construction and definitions of the data used for this growth accounting exercise are discussed in detail. We give an overview of the sources and definitions of data on value added, employment (hours work) by skill, investment by IT and non-IT assets, but also price deflators of value added and investment, wages by skill, rental prices of capital by assets by industry. This appendix also gives the definition of the data used in the MFP-growth estimations of Table 3.

Definitions and data sources for growth accounting

Provinces, industry classification and sample period

Our regional growth accounting database is subdivided according to provinces in The Netherlands (figure A1). The industry classification used in this growth accounting is based on the highest common level of aggregation for the variables involved, which is the industry classification of regional investments by asset type. This classification is presented in Table A6 along with the corresponding ISIC classification. Investments by asset, industry and region are only available from 1995 onwards. This means that, despite availability of longer series for other variables, out regional growth accounting database is limited to the period 1995-2002.

Figure A1. Provinces in The Netherlands

Table A6. Industry classification used for the growth accounting

Number	Industry	ISIC
1	Agriculture and fishery	01-05
2	Mining and quarrying	10-14
3	Manufacturing and utilities	15-41
4	Construction	45
5	Trade and hotel business	50-55
6	Transport and communication	60-64
7	Financial and business services	65-74
8	Social and non-market services	75-99

The presence of mining, mainly winning of natural gas, is hardly connected to the local provincial economy. Moreover, 60% of the total value added of Dutch mining stems from one province (Groningen). That is why we have excluded mining throughout this paper. The same is true for real estate (ISIC 70), because we focus on the productivity contribution of business-related assets and not residential buildings (see also OECD, 2001).

Value added and value added deflators
Data on value added by region and industry are all drawn from Statistics Netherlands, *Regionaal Economische Jaarcijfers* (in English: *Regional Account Statistics*). This data source corresponds to the National Accounts and is based on extensive firm-level surveys. One of those is the *Productiestatistieken (Production Censuses*) that cover all firms of more than 20 employees, while smaller ones are sampled. They provide information on production, value added and investment. Another is the *Enquête Werkgelegenheid en Lonen* (*Survey of Employment and Wages*), which forms the heart of the *Labour Account Statistics*, which is composed similarly and covers 75% of all jobs in The Netherlands.

In this study, aggregate regional value added is always excluding the value added of mining and real estate of that region. All value added data are aggregated to the classification of Table A6. The *REJ* also provides value added price deflators by region and industry. These are in fact based on the national deflator adjusted for differences in regional sector composition, but will nevertheless be used for deflating value added.

Labour by skill
Labour data are subdivided in employment of employees and self-employed. Employment of employees in full-time equivalent labour years by industry and region is, like value added, drawn from Statistics Netherlands, *Regional Accounts*. Statistics Netherlands *Labour Accounts* provides information on the annual number of hours worked per full-time labour year per industry. We assume that there are no regional difference in these industry full-time hours worked. Combining *Regional Accounts* and *Labour Accounts* yields the number of hours worked per employee by region and industry.

The hours worked by self-employed are assumed to a simple mark-up over the employee hours worked, based on the self-employment-employee ratio by industry drawn from Statistics Netherlands, *Enquête Beroepsbeolking* (*Labour Force Survey)*. This means that all self-employed are assumed to work full-time only.

The number of hours worked by level of skill is based on the *Labour Force Survey* as well, which yields information of the employed labour force by region, industry and level of educational attainment. Table A7 presents the classification used here.

Table A7. Skill levels used in this study and corresponding level of education

Skill level	Education level in The Netherlands
Low	Primary education and below
	Lower vocational, lower general (Vmbo)
Intermediate	Intermediate vocational (Mbo)
	Intermediate general (Havo and Vwo)
High	Higher vocational (Hbo)
	University

The Dutch *Labour Force Survey* is based on a relatively small sample of persons being questioned. This means that for sparsely inhabited provinces, like Drenthe, Flevoland and Zeeland, the data are susceptible to erratic fluctuations because of differences in the regional sample size of each annual wave of the survey. In order to circumvent this problem, we have used three-year averages for the employment figures by skill, industry and region. The average skill shares that are found in this way are used to get hours worked by skill type.

Investment by asset
Investment data by industry and region and by asset and region are drawn from the *Regional Accounts*. The investments of the finance and business services sector include investment of real estate companies. Therefore investment in residential buildings by region is subtracted from investment of financial and business services to yield investment net of real estate.

Investment by region, industry and asset type (IT versus non-IT) is only available for business related sectors, i.e. not for agriculture (ISIC 01-05) and government services (ISIC 75-80). Data for these industries are only available on a national scale. Therefore the shares of IT investment in national agriculture, in national government services and education and in national health care are used to construct regional investments by type for these industries. For business related sectors (ISIC 10-74, 90-99) data on investment by asset, industry and region are available from the *Production Censuses*. Possible missing observations for these industries are interpolated based on the industry/region trends. This procedure yields the share investment in IT assets by industry and region, which generates the actual IT investments and non-IT investments by industry and region.

Regional investment deflators are not available, which is why national investment deflators by industry and asset type are used for deflation. The means that we assume no regional differences in investment prices by industry and asset type.

Labour compensation by skill
Equations (5)-(8) show that for growth accounting information on the compensation of each of the inputs is necessary. For labour this implies the availability of costs by region, industry and skill type.

Annual labour compensation per employee by region and industry is available from the *Regional Accounts*. Given the annual number of hours worked per employee, it is possible to obtain employee compensation per hour worked by region and industry. The associated compensation per self-employed per hour are simply assumed to be equal to 70% of the employee compensation (see Inklaar et al., 2003). Together with the total number of hours worked per self-employed this yield total annual labour compensation.

Next wage costs by skill type are drawn from Statistics Netherlands' *Loonstructuuronderzoek* (*Wage Structure Survey)*, held irregularly. This yields national employee wage costs per hour by industry skill level as defined in table A7. Possible missing years are interpolated using the trend of the annual growth rate of total employee compensation, which is available.

This yields data on national hourly compensation by industry and skill level. Next, with annual number of hours worked by employees, by industry, region and skill, constructed earlier on, it is possible to obtain the total annual wage payments by region, industry and skill type. The shares of wage payments by skill type obtained from these data are used to construct the total compensation of labour by region, industry and skill.

Depreciation rates by asset type
Depreciation is the change in value associated with the ageing of an asset. As an asset ages its price will change, because it declines in efficiency or yields fewer productive services in current and future periods. Depreciation rates depend on the service life of the asset involved. However, estimates of service lives based on statistical information are scarce, particularly services lives by industry and asset type. However, Meinen et al (1998) estimate service lives for as much as 22 industries and nine different assets for The Netherlands. These estimates are used to obtain service lives of non-IT and IT equipment for the Netherlands.

Like Meinen et al (1998) we assume a straight-line depreciation rate in which equal amounts of the value are deducted from of the capital stock every year by the size of.

$$\delta = 1/T \tag{A1}$$

where T is the asset service life.[9] Table A8 provides an overview of the life spans, based on Meinen et al, that we have used and the associated depreciated rates, using (A1).

Table A8. Life span of investment goods and depreciation by asset type and industry

	Service life (years)		Depreciation rate	
	IT assets	Non-IT assets	IT assets	Non-IT assets
Agriculture and fishery	4.0	23.8	0.249	0.042
Mining and quarrying	4.9	22.6	0.203	0.044
Manufacturing and utilities	5.6	29.8	0.178	0.034
Construction	7.7	21.5	0.130	0.046
Trade and hotel business	4.1	23.3	0.245	0.043
Transport and communication	3.6	21.7	0.276	0.046
Financial and business services	3.7	17.4	0.270	0.057
Social and non-market services	4.1	34.5	0.247	0.029

Note: excluding residential buildings

[9] As alternative to straight-line depreciation one could think of the declining balance or geometric depreciation $\delta=R/T$, where R is called the declining-balance rate. Fraumeni (1997) has estimated this factor R for a large number of assets for the USA. For a number of reasons we use the depreciation of (A1) instead of that of Fraumeni (1997). First, Fraumeni only estimates economy-wide rates of declining-balance, service lives and the associated depreciation rates. However, a computer in manufacturing is quite a different machine than one in, say, finance and consequently will have different service lives. Service lives estimated by Meinen et al. (1998) do differ by type and by industry. Second, we feel more comfortable using service lives data that correspond to the Dutch situation to those based on the USA. Third, Meinen et al (1998) also assume straight-line depreciation. Fourth, the main conclusions from this study do not change when the depreciation method with estimates of Fraumeni is applied. The contribution of non-IT capital deepening to productivity growth drops while that of MFP-growth increases, but the differences between regions remain.

Capital input
It is not so much the physical capital stock, but the flow of productive services from that stock that constitute an actual input in the production process. This flow of productive services is called capital services. Flows of capital services are usually not observed, so they are approximated by assuming that the service flows are in proportion to the physical stock of capital assets after each vintage has been converted to standard 'efficiency' units (OECD, 2001).

The investment series and depreciation rates are used to calculate capital stocks. Since there are no long regional investment series, we need to make an assumption regarding the starting value of the regional capital stocks with which to the regional capital build-up can be constructed using the perpetual inventory method (PIM). This assumption is based on similar capital-output ratios by industry for each region. The capital stock by industry and asset type for The Netherlands as a whole is available. First, these national industry capital stocks and the corresponding national industry value added are aggregated to the industry classification of Table A6. Next, we calculate the average capital-output ratio for each of these industries for The Netherlands as a whole over the period 1990-1994. These industry ratios are then used to calculate the starting value by industry per province for 1994 by multiplying them with the provincial industry output, where output is measured as value added.

This provides starting values by industry and province for 1994. Given the investment series, deflators and depreciation rates for 1995-2002, PIM can be applied to generate regional capital stocks by industry and by type as

$$K_{i,t} = I_{i,t} + (1-\delta_i)\cdot K_{i,t} \qquad \text{(A2)}$$

where K_i is the physical capital stock of asset i in constant prices, i is either non-IT or IT equipment, I_i is real investment of type i and δ_i is the depreciation rate of asset i of Table A8. Next, this physical capital stock needs to be transformed in capital services.

Capital compensation
In order to do that we need an approximation for the price component of capital, in the form of user costs or rental prices. Rental prices represent the amount of rent that would have been charged in order to cover costs of an asset, or

$$r_{i,t} = (\rho_{i,t} + \delta_i) - \pi_{i,t} \qquad \text{(A3)}$$

where r_i is the rental price of asset i, δ is the depreciation rate, ρ is rate of return on (financing) capital, which usually is some market interest rate, and π is the inflation rate of the asset in question (OECD, 2001). The first term between parentheses measures the cost of financing the asset and the second term measures capital gains or losses of the asset. Rates of return to capital by asset type are taken from Inklaar et al. (2003). For all industries and assets we assume similar rates of return of 13% in 1995, 14% in 1996-1997, 15% in 1998-1999 and 17% in 2000-2002. Together (A1)-(A3) yield the capital services used in growth accounting, as can be seen from equations (1)-(6) in the main text.

Definitions, data sources and specification analysis for MFP-growth estimation

Table 2 shows the indicators that are used to further explain the regional MFP-growth in equation (19) that followed from the growth accounting.

Innovation/R&D
Innovation or R&D is assumed to have a positive effect on productivity growth. R&D expenditure per province are drawn from Statistics Netherlands, *R&D Statistieken* (*R&D Statistics*). We use expenses of private businesses, universities and other research institutions, because we explain economy-wide MFP-growth by province. As indicator in the estimation of (19) we use the share of total regional R&D in total regional value added.

Job density
As measure for agglomeration we use job density, composed of jobs of employees and self-employed by region divided by regional land surface, in jobs per hectare.[10] Jobs of employees by region are drawn from Statistics Netherlands, *Survey of Employment and Wages*, which are transformed into the total number of jobs of both employees and self-employed by a mark-up of the share of self-employed in the regional number of employees. The latter is drawn from Statistics Netherlands, *Labour Force Survey*. Statistics on regional land surface is also taken from Statistics Netherlands, *Bodemgebruik* (*Land use*).

Congestion
We use two indicators to represent the extent of traffic congestion. First, we apply the travel-to-work time per person (in minutes) of Statistics Netherlands *Mobility Statistics*. This indicator is based on the self-reported travel time of the respondents by region. This means that lost time due to congestion is included, but not possible differences in travel-to-work distance by region when commuters in Friesland, say, work on average at a more distant location than those in for example Zuid-Holland.

As second indicator we have calculated the number of cars in each province per kilometre of road in that province. The more cars per kilometre, the higher congestion is likely to be. The number of cars per region is drawn from Statistics Netherlands *Mobility Statistics*. Stretches of roads by region are available from Statistics Netherlands, *Land use*.

Labour effort
Labour effort can only be measured indirectly. As indicator that approximates labour effort we use the regional unemployment-vacancy (UV-)ratio. The UV-ratio is a general indication for labour market tension. The higher the UV-ratio, the higher the surplus of workers relative to available jobs is. This means that the risk that when loosing ones job, one looses ones source of income is large. In its turn this triggers incentives to avoid getting fired and one of those is to increase work effort. For low levels of the UV-ratio the opposite is true: even when one looses ones job, the low-UV-ratio guarantees that sufficient free jobs are available to find another. There are no strong incentives to high levels of work effort. The regional UV-ratio is calculated using data from Statistics Netherlands, *Labour Force Survey* and *Vacature-enquête* (*Vacancy Survey*).

Regulatory burden
There is as yet no statistical information on the regulatory burden per region, either on product market regulations, nor labour market regulations. Equation (19) therefore includes fixed effect dummies to grasp this and other missing aspects that affect MFP-growth.

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[10] Both numerator and denominator are excluding jobs and land use for mining.

Correlation matrix

It is likely that a number of these indicators are highly correlated. This affects the value and significance of the estimated parameters of (19), due to multicollinearity. In that case the different explanatory variables 'explain' nearly the same amount of variation in MFP-growth, so that the contribution of each separate explanatory variable becomes unreliable. Table A9 gives the matrix with simple correlations between each of the indicators discussed. There is no absolute rule that says when multicollinearity becomes a serious problem. We speak of 'serious' multicollinearity when $| \rho | > 0.5$, which is indicated by the shaded cells in the table.

Table A9. Correlation matrix of explanatory variables of model (18)

		1	2	3	4	5
R&D/value added	1	1.00				
Jobs/acre	2	0.34	1.00			
Travel-to-work time/person	3	0.33	0.60	1.00		
Cars/kilometre road	4	0.40	0.98	0.64	1.00	
UV-ratio	5	-0.47	-0.50	-0.16	-0.52	1.00

Table A9 shows that particularly job density is highly with the indicators of congestion. The two congestion indicators are also highly correlated. Hence the variables should enter the simultaneously in equation (19). There is also some correlation between labour effort and congestion, but to a lesser extent.

Based on the correlation matrix of A9 we start estimating (19) with R&D, job density and labour effort as explanatory variables. Furthermore, specifications with fixed effects (all other indicators that may affect MFP-growth) and without fixed effects (all indicators mentioned capture MFP-growth) are compared. The job density variable, which stands for agglomeration, is next replaced by the two congestion indicators.

Table A10. Estimation results of equation (19)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 5B
Intercept	5.48	-0.90	-20.2	-0.29	8.80	-0.75	7.80
	(2.13)	(-1.52)	(-2.86	(-0.12)	(3.20)	(-1.16)	(5.88)
Fixed effects	Yes	No	Yes	No	Yes	No	Yes
R&D-share	0.09	0.21	-0.21	0.24	-0.27	0.23	
	(0.15)	(1.06)	(-0.35)	(1.17)	(-0.52)	(1.13)	
Car density					-0.15	0.00	-0.14
					(-4.75)	(0.07)	(-6.08)
Travel time to work			0.38	-0.01			
			(2.75)	(-0.18)			
Job density	-0.02	0.00					
	(-3.52)	(0.69)					
Labour effort	0.13	0.18	0.08	0.17	0.07	0.17	0.09
	(2.73)	(3.77)	(1.16)	(4.46)	(1.36)	(3.68)	(1.80)
Adjusted R^2	0.33	0.18	0.34	0.17	0.39	0.17	0.40
Residual se	0.93	1.03	0.92	1.03	0.89	1.03	0.88
N	72	72	72	72	72	72	72

Note: *t*-values between brackets are based on the Newey-West covariances robust for heteroscedasticity and autocorrelation

Table A10 shows the estimation results of the specification analysis. Model 5B, which follows from model 5, is chosen as our preferred simplified model that represents regional MFP-growth best, in terms of adjusted R^2 and residual standard error. We first find that R&D as share of value added does not affect regional MFP-growth in The Netherlands. Second, of the related indicators for agglomeration and traffic congestion, car density, defined as cars per kilometre road in the region, performs the best, followed by job density. This means that heavy traffic congestion (i.e. many cars per kilometre road) hampers MFP-growth. Notice also that model 1 confirms the agglomeration disadvantage for productivity growth that was found by Broersma and Oosterhaven (2004). Third, labour effort has a positive effect on MFP-growth. Fourth, we do need other possible explanatory indicators to enter the model in the form of regional fixed effect dummies. These dummies represent all kinds of influences on MFP-growth that were neglected so far, like local and regional regulations. Sixth and finally, our indicators explain 40% of the variation in regional MFP-growth, so a substantial part is still left unexplained.

As a next step we estimate the same specification as 5B for the peripheral and core to assess the robustness for different compositions of regions. Table A11provides an overview of these results. We find evidence for the fact that in the core regions congestion in the form car density pays an important role, whereas in the peripheral regions it is the labour effort. When car density in the core regions rises with 1%, say, this raises congestion with 61,000 additional cars given the stretch of road, or almost one car per kilometre road extra in the core regions. This is about three times the average annual car growth rate in the core regions of the latest years. The resulting fall in mfp-growth of such a shock would imply a fall of 0.15%,. This means that the annual mfp-growth rate becomes a mere 0.85%, given the current growth rate of about 1%. In other words, when the average annual growth rate of the number of cars in the core region of the past years continues, then mfp-growth in this core region will drop by 0.05 percentage points each year relative to the actual growth rate.

A drop in labour effort in the periphery of 1%, on the other hand, corresponds to a drop in unemployment of 13,0000 persons given vacancies, or a rise in vacancies of 4,000 given unemployment. This is almost twice as large as the average fall in unemployment in the periphery between 1996 and 2002 and almost three times the average rise in vacancies. The resulting fall in mfp-growth to such a shock is 0.22%, so periphery mfp-growth would become 1.35%. Hence, a 'normal' increase in labour effort in the periphery would add approximately 0.09 percentage points to the annual mfp-growth rate in the periphery.

Table A11. Estimation results of (19) for the core and peripheral regions

	Core regions		Peripheral regions	
	Model 5B	Simplified	Model 5B	Simplified
Intercept	10.61	8.72	7.24	0.44
	(6.11)	(6.61)	(1.30)	(0.97)
Fixed effects	Yes	Yes	Yes	Yes
Car density	-0.18	-0.15	-0.31	
	(-7.32)	(-7.49)	(-1.21)	
Labour effort	-0.10		0.15	0.22
	(-1.27)		(2.38)	(4.70)
Adjusted R^2	0.37	0.37	0.47	0.47
Residual se	0.87	0.87	0.83	0.83
N	42	42	30	30

Note: *t*-values between brackets are based on the Newey-West covariances robust for heteroscedasticity and autocorrelation